Model 8600A
Digital Multimeter

Student Handout

FLUKE®

Foreword

This training course has been prepared by the Customer Service Department of the John Fluke Mfg. Co., Inc. to assist the experienced technician to understand how the instrument works, how to calibrate it and how to maintain it. Should you have any questions, comments or suggestions about this course of instruction please feel free to communicate them to the Training Department by letter or telephone.

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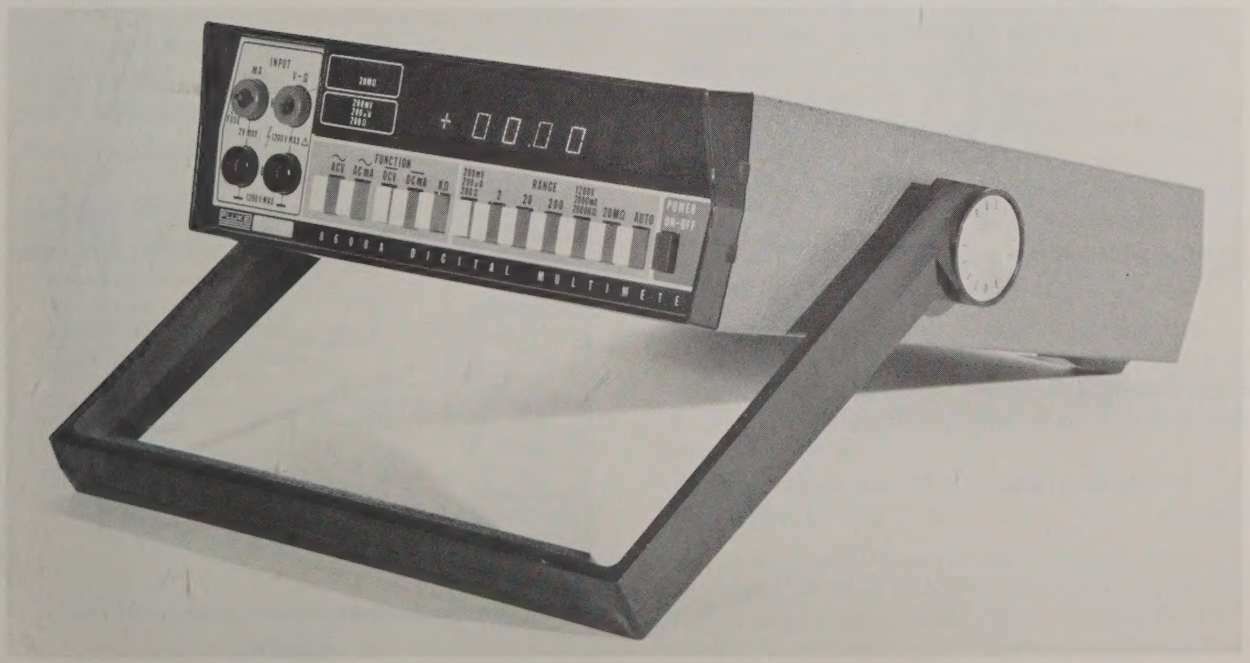


INTRODUCTION

Rapid and efficient repair of any instrument is greatly enhanced by a thorough understanding of the theory of operation. The purpose of this book is to present the reader with enough information about the theory of operation and methods of repair to make it possible for a technician to efficiently maintain the Model 8600. This book is intended to supplement the Audio-visual training program on the Model 8600 Digital Multimeter.

The 8600 is a 4½ digit DMM, with an LED readout, featuring pushbutton selection for 5 ranges each of dc and ac volts, dc and ac current and six ranges of resistance. Autoranging and autozero are standard features of this instrument. This instrument has a reading rate of 2½ samples per second.

All dc voltage ranges (200mV, 2V, 20V, 200V, 1200V) are continuously protected to ±1200 Vdc or 1700 Volts peak ac. In the resistance ranges (200Ω up through 20 megohms) the 8600 will withstand a continuous 250 Vrms or dc. A 2 amp front panel fuse protects all ac and dc current ranges.

Some new symbols appear on the front panel of the 8600. These symbols are standards adopted by the IEC (International Electro-technical Commission) and are explained as follows:

WARNING SYMBOLS

a. If, to preserve the apparatus from damage, it is necessary for the user to refer to the instruction manual, the apparatus shall be marked with the symbol:

The symbol shall be placed adjacent to the device to which it applies.

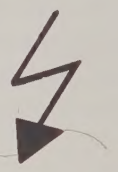
TERMINALS AND OPERATING DEVICES

All terminals and operating devices shall be identified by inscriptions or symbols making clear, if possible, the intended purpose of that device and corresponding to the relevant explanation in the instruction manual.

The following terminals and devices shall be marked in particular:

a. Earth terminals of measuring and control circuits connected to accessible metal parts under the provisions of Sub-clause 35.9 and whose connections are not self-evident, with the symbol:

b. Terminal devices fed from the interior by live voltages, that may be dangerous when connecting to or disconnecting from these devices shall be marked with the flash shown when the voltage exceeds 1 kV:



The 8600 will accept a variety of options, which include:

High Voltage Probe
RF Probes
High Current Probe
Deluxe Test Leads
Carrying Cases
Rack Mount Kits
(offset, center, and dual)

As a note of interest, the Model 8600 does not utilize the Recirculating Remainder technique for Analog-to-Digital Conversion, but rather a dual slope technique with a FLUKE designed Large Scale Integration (LSI) chip which gives the instrument outstanding performance with a limited number of parts.

BLOCK DIAGRAM ANALYSIS

The following analysis of the 8600A is done in a block diagram format for ease of understanding. Figure 1 is that block diagram to which you should refer to in this analysis.

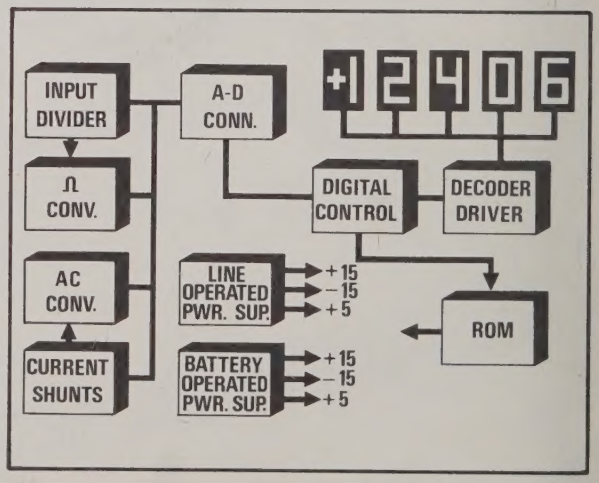


Figure 1.

Power Supplies

The 8600 can be powered by either a line operated or battery powered power supply. Either supply will generate a + or −15 Volts for operating voltage and a +5 volts for logic voltage. These voltages are regulated and filtered.

Input Divider

In the dc volts mode, the input divider offers an input impedance of > 1000 mΩ for the 200 mV and 2V ranges, while offering 10 MΩ in the 20V, 200V, and 1200V ranges. For ac inputs the input divider impedance is 2 MΩ shunted by less than 100 pf. For analysis purpose let us assume that the 8600 is set to the VDC mode of operation. In this mode the input divider confines it's output voltage within one of two basic ranges, 0 to ±.2V or 0 to +2V, and applies that to the Analog-to-Digital Converter.

ANALOG-to-DIGITAL CONVERTER (Figures 2 & 3)

As we stated earlier, the 8600 uses a dual slope method of analog-to-digital conversion. The A-to-D Converter in the 8600 (Figure 2) consists of a Buffer Amplifier, an Integrator and a Comparator which then feeds a Digital Chip. Although this chip is shown in the Block Diagram, Figure 1, as a separate block in reality it is an integral part of the A-to-D Conversion. It is shown separately for ease of discussion.

The Integrator circuit converts the buffered input voltage into a charge placed onto a capacitor. This charge, Figure 3 takes place for 100ms. (Integrate time) The level of the charge, VT_1, depends upon the input voltage. After 100ms the applied input voltage is replaced with a reference voltage, in opposite polarity to the input, which causes the charged capacitor to discharge back to zero. This discharge (Read time) takes place within a variable time frame, dependent upon the initial charge level. Thus the comparator, fed by the Integrator, will convert the charge, discharge action into a digital

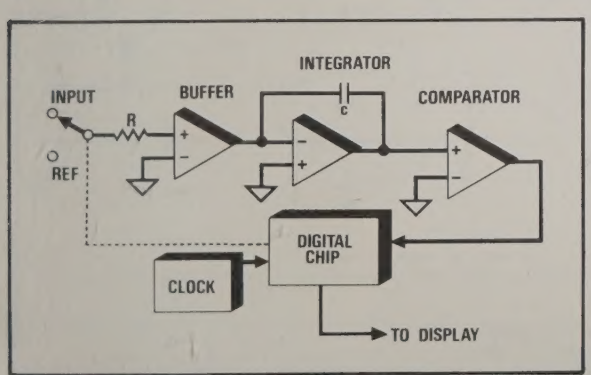


Figure 2.

command, the duration of which is variable as a direct result of the charge level of the integrator capacitor and its discharge time. This variable duration command is then fed to the Digital Chip.

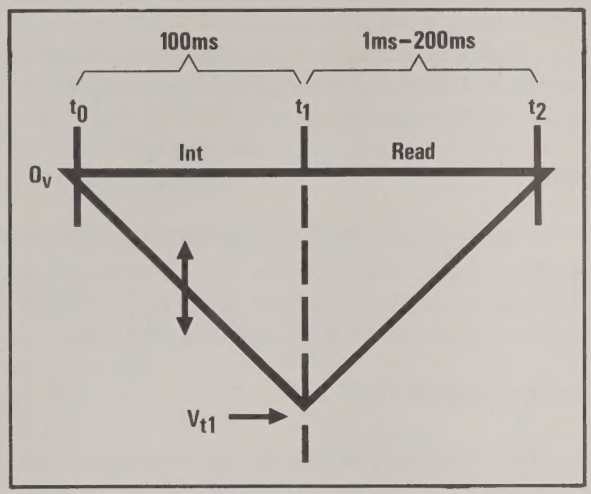


Figure 3.

DIGITAL CHIP

An LSI, of special design, contains all the circuitry for this block, whose purpose is to 1) set the timing of the instrument, and 2) convert the digital information from the comparator into a BCD count.

When the integrator capacitor starts to charge, the Comparator output will be set to a prescribed level. This will cause a counter, contained within the digital chip to count the pulses from a 1 MHz clock. This counter will in fact count up to 100,000 pulses. At the 100,000th pulse from the clock, 100ms duration, the counter is cleared causing the input on the A/D Converter to switch from sampling the input to receiving a reference voltage. This will cause the integrator capacitor to discharge, keeping the comparator output set to the level achieved during the charge. During this discharge time the counter will count the pulse inputed from the clock and convert those pulses into a BCD count which is representative of the input voltage. The BCD count is fed to a decoder driver.

Strobing commands used to control the display are also generated within this chip, as well as range commands used to control a ROM.

DECODER DRIVER

The Decoder Driver converts the BCD count out of the Digital Chip into a decimal format by setting to a low level the proper combination of decimal lines into the LED's. As

is the case in most Fluke DVM's or DMM's the 8600 uses a single decoder driver, thus reducing the total parts count and possible failures.

DISPLAY

The Display is made up of five LED's, four of which are seven segment, while the overrange digit is a five segment showing polarity and overrange.

ROM

A bipolar ROM is used to control the ranges of the 8600. This ROM controls relays contained within the Input Divider, AC Converter, and Ohms Converter. Range and function information are fed into the ROM from the Digital Chip.

OHMS CONVERTER

The Ohms Converter gives the 8600 six ranges of fully automatic resistance measuring. In the Ohms configuration, this converter supplies a known current to the unknown resistance which is connected across the input terminals. The resultant dc voltage is then applied to the Analog-to-Digital section. The Input Divider is used as part of the circuitry of the Ohms Converter.

AC CONVERTER

The ac input is scaled to an appropriate level and converted to dc. This dc voltage is then fed to the A-to-D Converter section. There are five ranges of ac from 200mA up to 1200V.

CURRENT SHUNTS

The 8600 has the capability of measuring either ac or dc current. AC current is first applied to the Current Shunts where it is converted to an AC voltage which is then applied to the AC Converter for conversion to a proportional dc voltage. DC current is applied to the current shunts where it is converted into a proportional dc voltage then applied to the A-to-D converter section. There are five ranges each for either the AC or DC Current modes.

SCHEMATIC DIAGRAM ANALYSIS
Power Supplies (Figures 4 & 5)

Line Operated - Figure 4

Line power is applied through fuse F2, Power switch S13 to the primary of T1.

±15V SUPPLY

AC secondary voltage off T1 is applied to a bridge rectifier, then across filtering, C101. This voltage is then fed to Regulator U101, the output of which is +15V. The −15V supply uses the same bridge network with filtering accomplished by C102 and regulation by U101.

+5V SUPPLY

AC voltage from a separate secondary winding of T1 is fed to another bridge rectifier network, across filter C103, and applied into Regulator U102. This is the +5V supply used for the logic levels of this instrument.

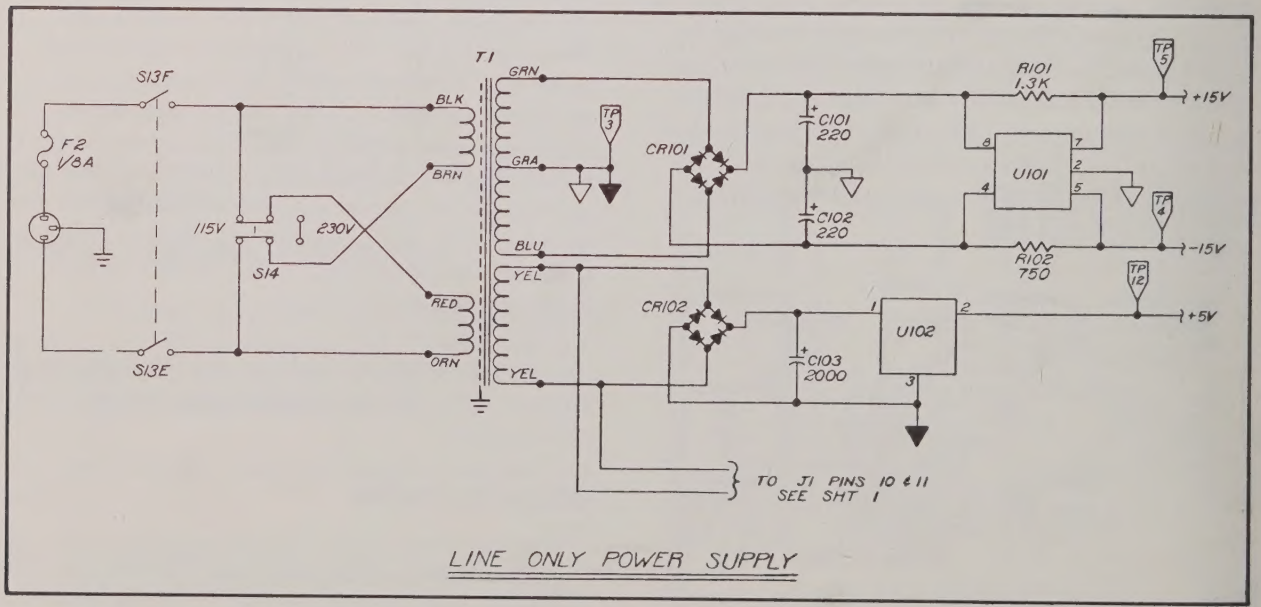


Figure 4.

Battery Operated (Figure 5a & b)

When the 8600, containing the Battery Operated Power Supply, is connected to AC line power (Figure 5a) and the power switch (S13) set to OFF, the AC line will be applied to a portion of T1 primary, CR21, CR23, and the RC network of R201, C201, with Fuse F2B providing protection. In this condition 400ma is supplied to the batteries, BT1 through BT4, for recharging. When the Power Switch (S13) is set to ON, Zeners CR21, CR23 are shorted and the full primary of T1 is utilized. The secondard voltage is then rectified by diodes CR201 and CR202. In the ON condition the current requirements of the 8600 increases to 500ma. Of that 500ma, 150ma is supplied to the batteries. +5 volts from the batteries is then utilized for the logic voltage within the 8600, and this +5V is also supplied to an inverter (Figure 5b) formed by transistors Q201, Q202 and transformer T_2. Secondary voltage from T_2 is applied to a full-wave rectifier. CR203 through CR206 which is then filtered by C202 for the + supply and C203 for the – supply. Regulator U201 is used as a regulator for both the + and –15V supplies.

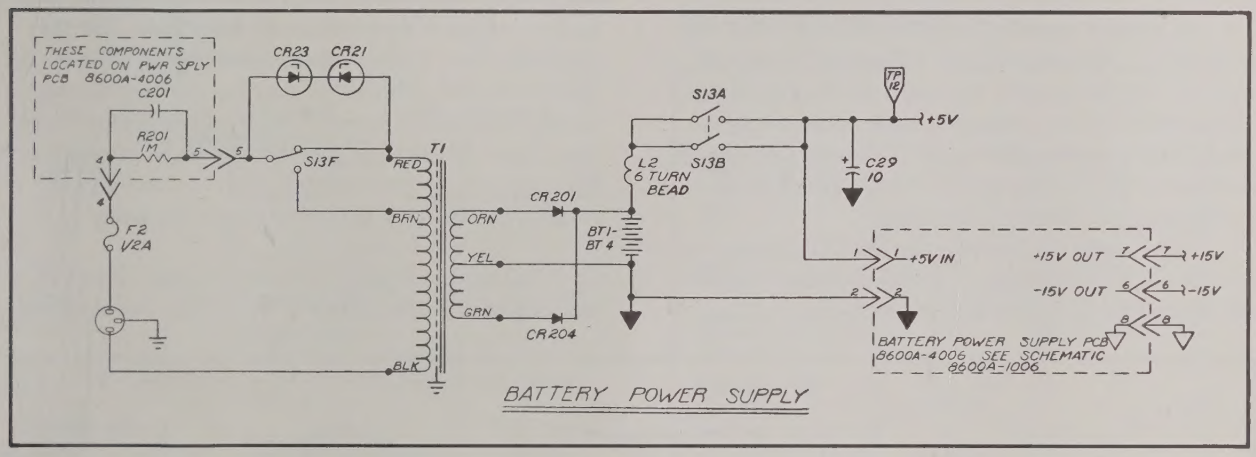


Figure 5A.

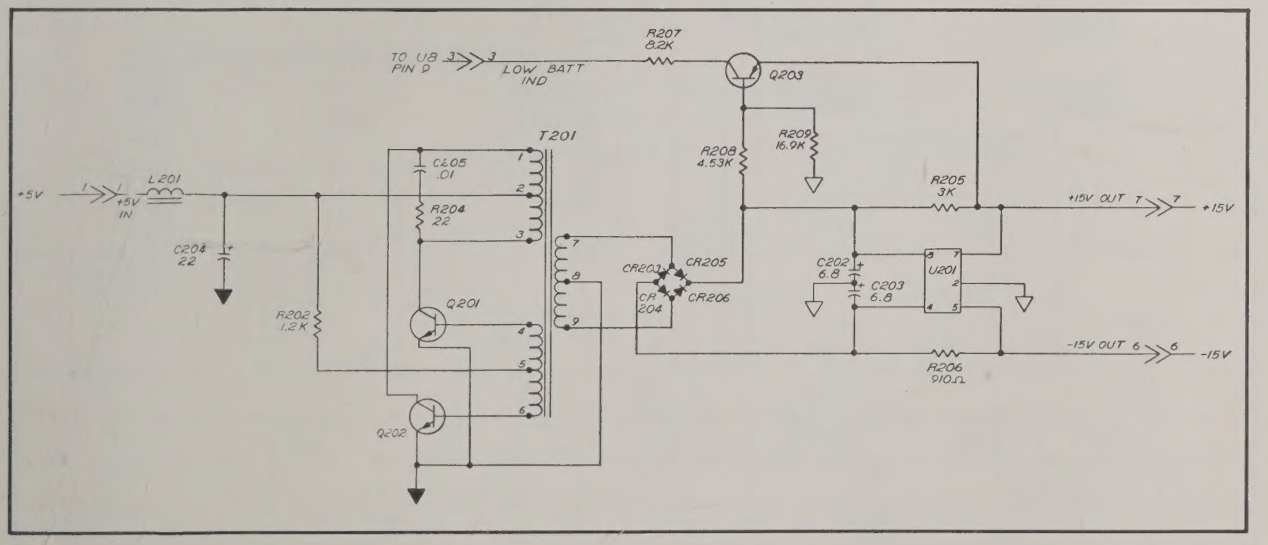


Figure 5B.

ANALOG TO DIGITAL CONVERTER
Figures 6, 7 & 8

The input to the Analog to Digital Converter (Figure 6) is always a dc voltage within one of the two basic ranges of the 8600, those ranges being 0 to + or −.2V or 2V. This dc input is applied to U4 through FET Q14, which is enabled by the action of Q10. When the $\overline{\text{INT}}$ command goes low, Q10 will be disabled. This will effectively set the level of the gate of Q14 more positive, enabling it, thus the input voltage will be applied through Q14 into the A-to-D Converter.

U4, a buffer amplifier, amplifies the input voltage and applies that to the integrator, U5. Capacitor C28, located across U5, will charge up to the output of U5. This charge, seen in Figure 7 as the integrator output, occurs during the integrate time and is applied to U6, the Comparator, causing its output to either go high (+5V) or low (zero volts), depending upon the polarity of the charge.

At the end of the Integrate time the $\overline{\text{INT}}$ command, on the base of Q10 will go high, (Figure 8) enabling Q10 which will disable FET Q14. This will remove the input voltage from the input to the A-to-D Converter. The command $\overline{\text{DE(+R)}}$ is utilized when the sampling input to the A/D converter is a negative voltage. This will disable Q26 and enable FET Q16. This will apply a plus reference voltage from the reference divider through U17, Q16 and into the first stage of the A-to-D Converter U4. Since there are two basic ranges within the 8600, there are two taps on the reference divider. Selection of the proper tap is accomplished by U17. Connections through U17 can be seen in Figure 6b.

With the + voltage now applied from the reference divider into the A-to-D Converter, Capacitor C28 will discharge back to zero, seen in Figure 7 as the Read Time. This time is variable (1ms - 200ms) and depends upon the initial charge placed upon C28. This discharge action will keep the output of U6 (CM in) at the same level it was during the charge time. Since the discharge is variable the length of time that U6's output is set is also variable. The command $\overline{\text{DE(−R)}}$ is used when the input to the 8600 is of a + polarity.

Referring to Figure 8, the timing diagram, after C28 has discharged and the output of U6 (CM in) changes states,

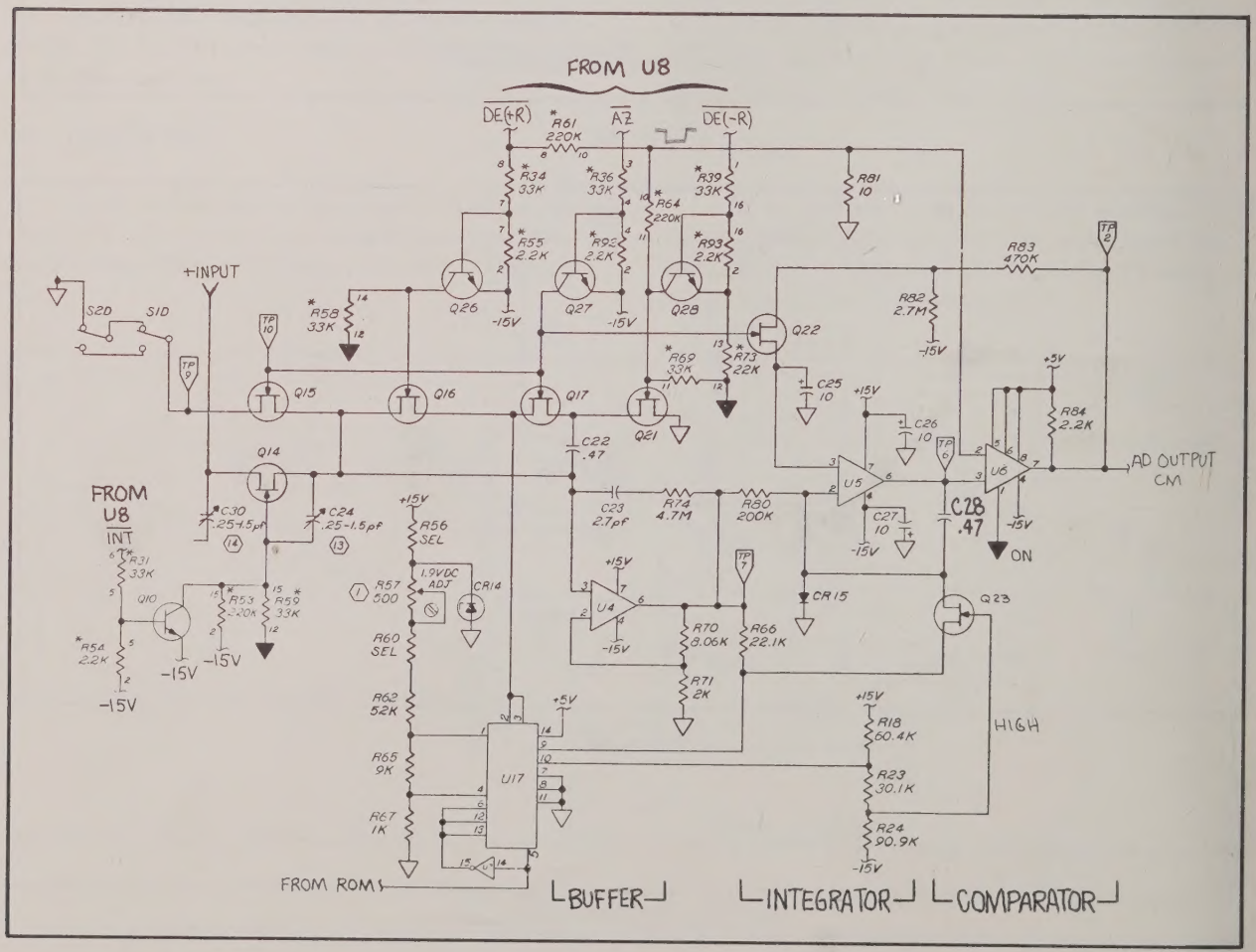


Figure 6A.

the command $\overline{AZ}$ will go low. This is the Auto Zero time period of the 8600.

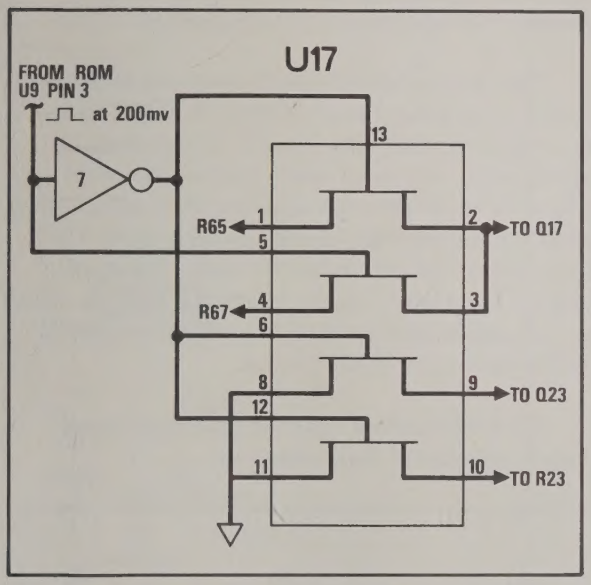


Figure 6B.

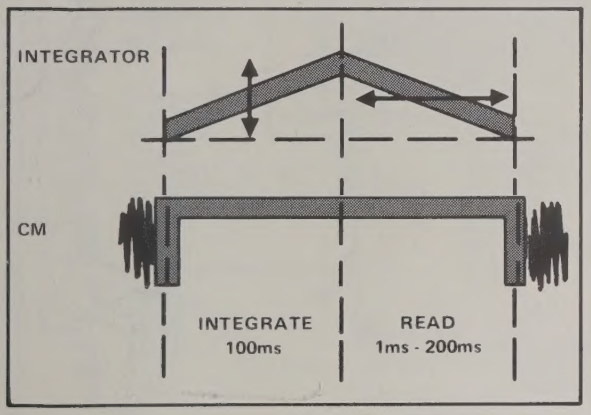


Figure 7.

When the $\overline{AZ}$ command goes low Q27, Figure 6, is disabled, enabling FETS Q15, Q17. With Q15 enabled, the input to the A-to-D Converter is shorted to ground, while at the same time Q17 will apply the reference voltage through it onto capacitor C22, which will be utilized with a + input after the input voltage is disconnected from the input to the A-to-D Converter.

The gain of the A-to-D Converter is controlled by Q33 and U17. This sets the gain to one of two possible conditions compatible with the basic range of the instrument as set by the Input Divider. The output (Cm in) of the Comparator (U6) is applied to the Digital Chip.

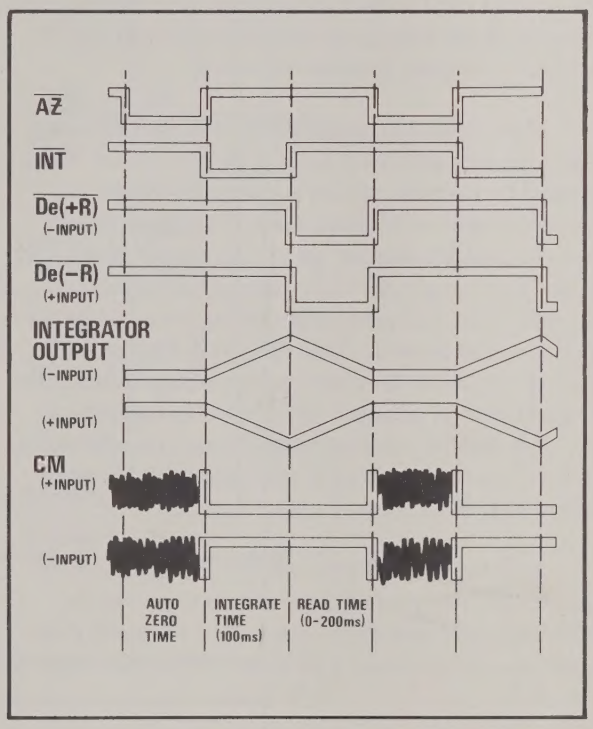


Figure 8.

DIGITAL CHIP (Figures 9 & 10)

This chip generates the timing commands $\overline{AZ}$, $\overline{DE(-R)}$, $\overline{DE(+R)}$, and $\overline{INT}$ for use in the A-D Converter; strobing pulses ST0 through ST7 for use in the display; range commands a, b, c; Decimal Command DPL; and the BCD Count WXYZ.

When the CM in command from the A-D Converter is set to +5V, or zero volts, the 1 MHz output from the oscillator is counted by a counter contained within this chip. During the time that the command $\overline{INT}$ is low this counter will count up to 100,000 pulses. On the 100,000th pulse the $\overline{INT}$ command will be caused to go high, thus disconnecting the sampling input to the A-D Converter. That period of time, up to 100,000th pulse, is the INTEGRATE period and is 100ms in duration, as set by the counter.

Next, either the command $\overline{DE(-R)}$ or $\overline{DE(+R)}$ will go low, depending upon the polarity of the input signal. These commands, when low, will cause a reference voltage, of opposite polarity to the input signal, to be placed on the input to the A-D Converter, causing the integrating capacitor to discharge, keeping the CM_{in} command set. During this time (READ period) the oscillator pulses are again counted by the internal counters. Since this period of time varies from 1ms to 200ms the pulses counted will depend upon the length of time for counting. This count, representative of the input signal, is converted into a Binary Coded Decimal (BCD) format by the counters, and is applied to the decoder on the W, X, Y, and Z output lines.

Strobing pulses ST0 through ST7, also generated by this chip, are used internal of the chip to strobe out the BCD count from each digits' counter, plus externally these pulses are used to strobe on the proper LED in the Display Circuit.

Range information, in BCD format, is applied from this chip on the a, b and c output lines to a Bipolar ROM. This Range coding, which is derived internally, is dependent upon the level of the α and β inputs to the Digital Chip. In the Manual range condition (Figure 10), all functions, U16 will short α and β lines together.

Then, when selecting a specific range, one of the strobing pulses will set the α and β lines to +5V. This input coupled with the clock input and the internal use of strobing pulses, will set the desired internal range of the instrument. In the autorange condition (DCV, ACV, DCMA, and ACMA functions) the β line is controlled by the ST1 pulse and α is controlled by the ST5 pulse. This sets the upper and lower ranges available. In the KΩ function another range is available therefore the α line will be controlled by ST6 through U16 in the KΩ function.

DPL (Decimal Place Left) is an internal command which is controlled by the strobing pulses.

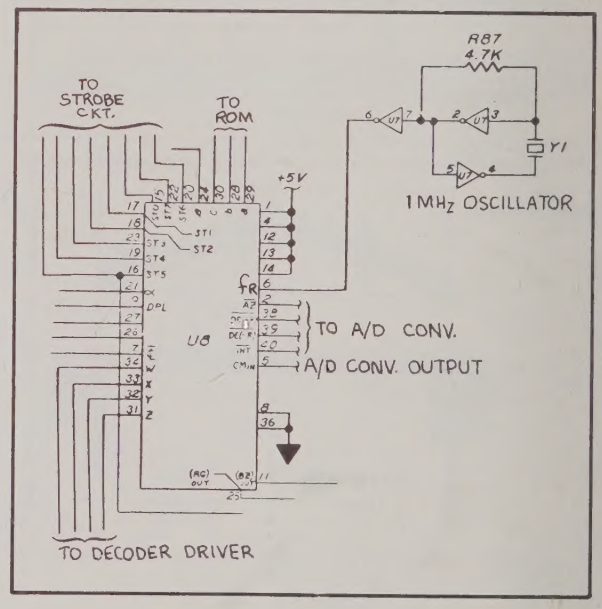


Figure 9.

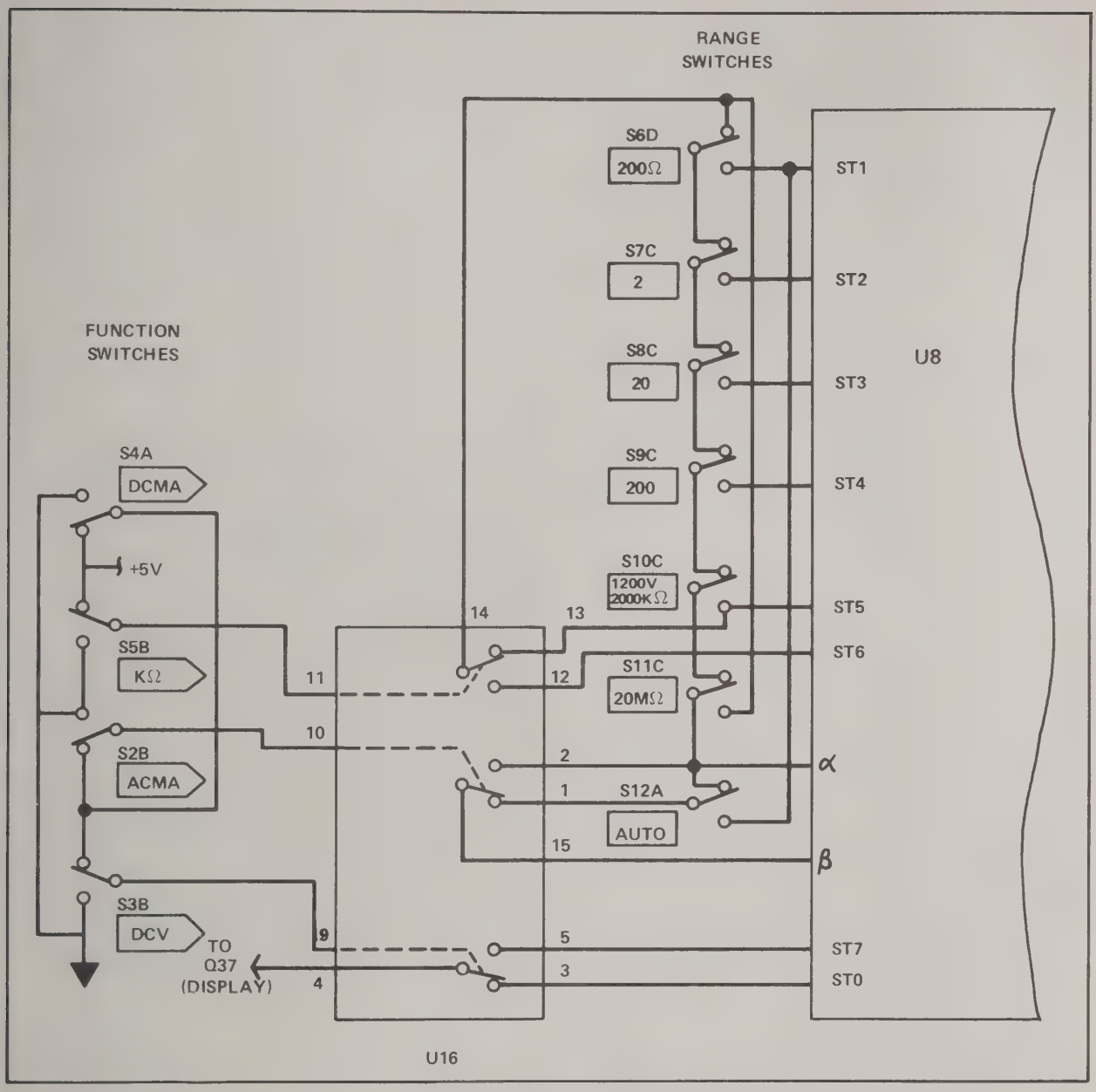
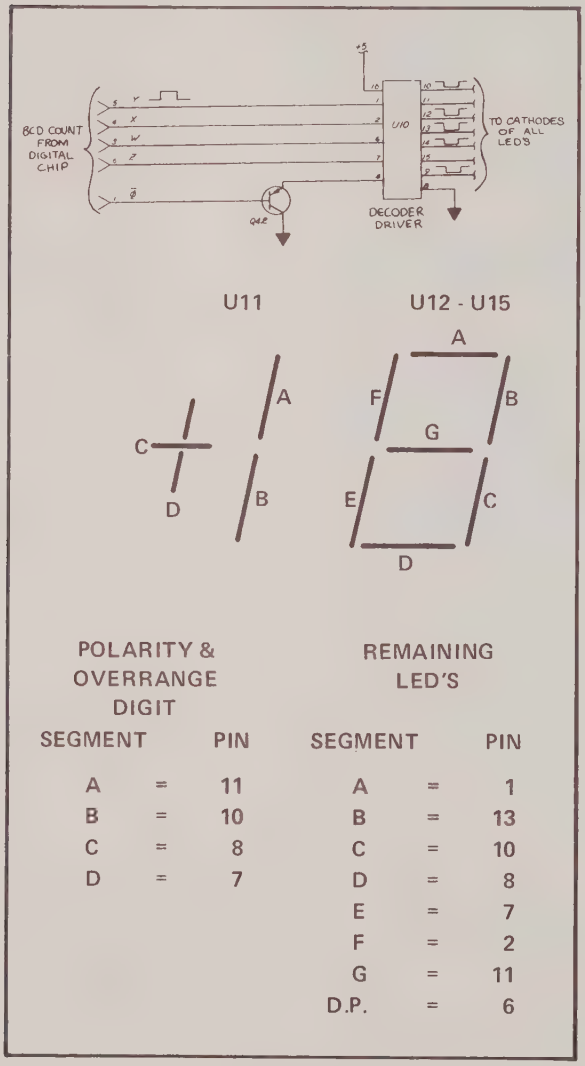

RANGE
SWITCHES
S6D
200Ω
ST1
S7C
2
ST2
S8C
20
ST3
S9C
200
ST4
S10C
1200V
2000KΩ
ST5
ST6
S11C
20MΩ
U8
FUNCTION
SWITCHES
S4A
DCMA
+5V
S5B
KΩ
S2B
ACMA
S3B
DCV
TO
Q37
(DISPLAY)
14
13
12
11
10
2
1
15
S12A
AUTO
α
β
9
5
4
3
ST7
ST0
U16

Figure 10.

DISPLAY (Figures 11 & 12)

The BCD count for each digit is strobed out of the separate counters within the Digital Chip and applied to the decoder driver, Figure 11, which decodes that BCD information into a decimal format by driving to a low level the proper combination of its output lines, which will be applied to the LED's.



POLARITY & OVERRANGE DIGIT			REMAINING LED'S		
SEGMENT		PIN	SEGMENT		PIN
A	=	11	A	=	1
B	=	10	B	=	13
C	=	8	C	=	10
D	=	7	D	=	8
			E	=	7
			F	=	2
			G	=	11
			D.P.	=	6

Figure 11.

Referring to Figure 12, the strobing commands are sequential starting with ST0. When ST7 returns to a low level S0 will go high repeating the cycle. When ST4 goes high Q31 will be enabled which will cause a low potential to be placed onto the base of Q32, enabling it. This will apply a +5V through Q32 to U13 and cause it to be strobed on. This display is strobed on by ST1, ST2, ST4, ST6 and ST7. ST3 and ST5 are used as time periods for autoranging.

The decimal point left command (DPL) is used to properly place the decimal in the display. This command controls Q39 which will set the decimal point in each LED to a low level. The proper position is attained from the strobing pulses.

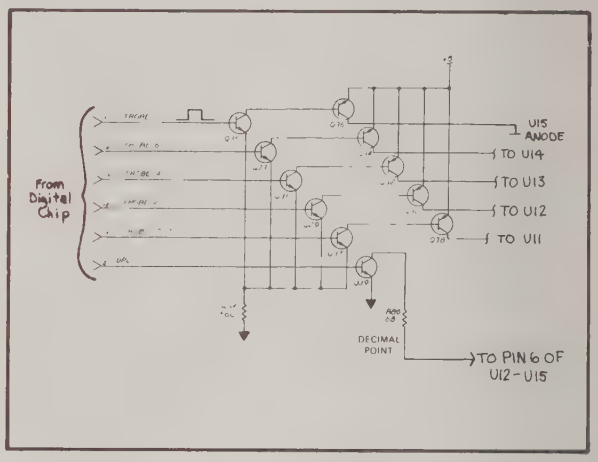


Figure 12.

The Annunciators, Figure 13, (upper and lower) visually tell the operator that the instrument is either in 200mV, 200uA, or 200Ω (lower Annunciator) or 20MΩ (upper Annunciator). In the case of being in the 20MΩ range, Q40 would be enabled thus applying +5V through it to CR3 causing it to illuminate and display 20MΩ on the upper left corner of the front panel display.

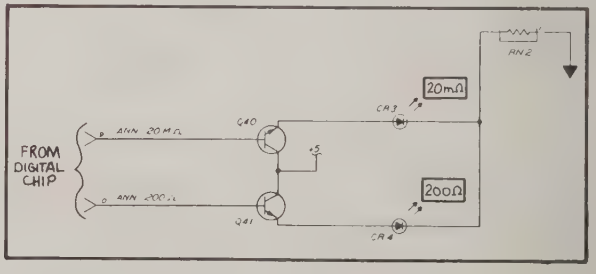


Figure 13.

BIPOLAR ROM (Figure 14 & Table 1)

The Bipolar ROM is used to properly condition the internal circuitry of the 8600 for the different ranges allowed within the called function. Since the 8600 has a autorange feature, range information received from the digital chip is fed into the Bipolar ROM which then conditions relays K1 through K8 to the condition for proper ranging. Table 1 shows the relay conditions for all ranges with the different functions.

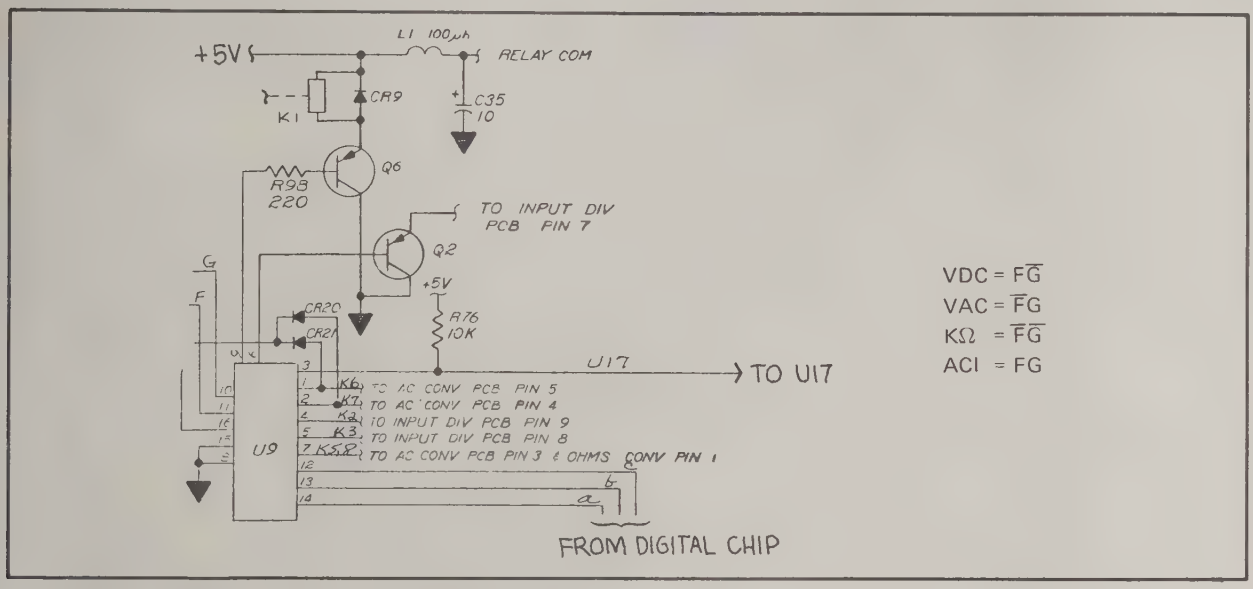


Figure 14.

U9 PIN	G 10	F 11	c 12	b 13	a 14	INSTR. RANGE	K6 1	K7 2	U17 3	K2 4	K3 5	K4 6	K5,8 7	K1 9	RANGE
VDC	0	1	1	0	1	1200V	1	1	0	1	1	0	1	0	5
	0	1	1	0	0	200V	1	1	0	1	0	1	1	0	4
	0	1	0	1	1	20V	1	1	0	0	1	1	1	0	3
	0	1	0	1	0	2V	1	1	0	1	1	1	1	1	2
	0	1	0	0	1	200mV	1	1	1	1	1	1	1	1	1
VAC	1	0	1	0	1	1200V	1	1	0	1	1	0	0	0	5
	1	0	1	0	0	200V	1	0	0	1	1	0	1	0	4
	1	0	0	1	1	20V	0	1	0	1	1	0	1	1	3
	1	0	0	1	0	2V	1	1	0	1	1	0	1	1	2
	1	0	0	0	1	200mV	1	1	1	1	1	0	1	1	1
kΩ	0	0	1	1	0	20m	1	1	0	1	1	1	0	1	6
	0	0	1	0	1	2000k	1	1	0	1	1	1	1	1	5
	0	0	1	0	0	200k	1	1	0	0	1	1	1	1	4
	0	0	0	1	1	20k	1	1	0	1	0	1	1	1	3
	0	0	0	1	0	2k	1	1	0	1	1	0	1	1	2
	0	0	0	0	1	200Ω	1	1	1	1	1	0	1	1	1
ACI	1	1	1	0	1	2000mA	1	1	1	1	1	0	1	1	5
	1	1	1	0	0	200mA	1	1	1	1	1	0	1	1	4
	1	1	0	1	1	20mA	1	1	1	1	1	0	1	1	3
	1	1	0	1	0	2mA	1	1	1	1	1	0	1	1	2
	1	1	0	0	1	200μA	1	1	1	1	1	0	1	1	1

Rom Program

0 = RELAY ENERGIZED
1 = OUTPUT HIGH

Table 1.

INPUT DIVIDER (Figures 15 & 16)

Figure 15 is the overall diagram of the Input Divider. Resistors R1, R3 thru R8 & R12, plus switches S1 A–C, and Relay Contacts K1B, K2 thru K4 comprise the input divider. DC input voltages are applied to this divider where the input is attenuated down to a voltage within the basic range of the instrument (0 to ±.2V or 2V). Relays K2 through K4 are controlled by the Bipolar ROM which is itself controlled by range information received from the digital chip. For manual range selection the range code is controlled by the range selected by depressing of the range pushbottons.

Figure 16 shows the configuration of the input divider in the VDC mode and VAC mode. To find out when the relays are activated refer to Table 1, ROM PROGRAM.

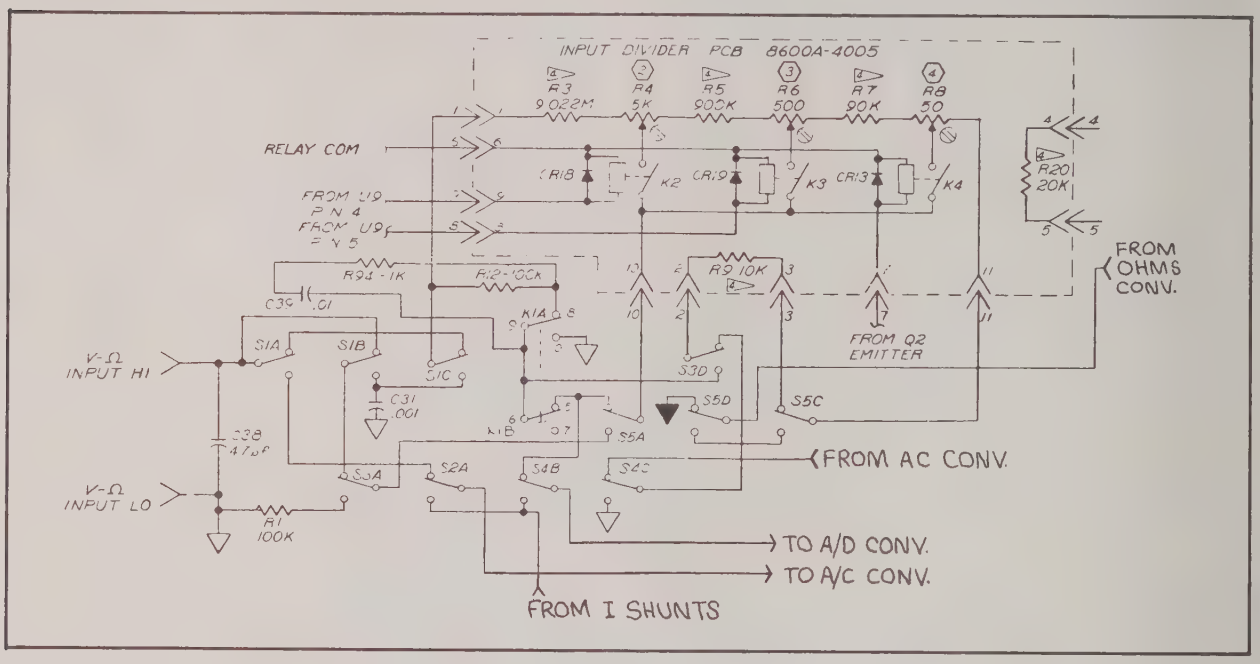


Figure 15.

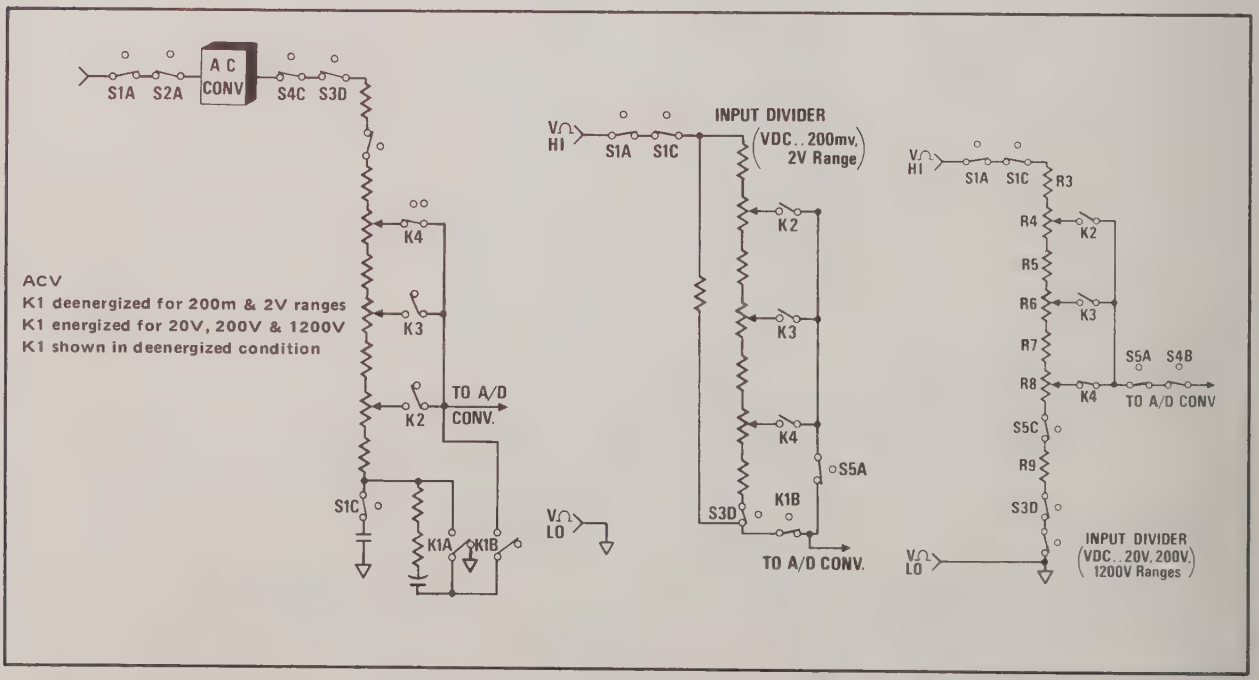


Figure 16.

AC CONVERTER (Figure 17)

It is the purpose of the AC Converter to convert AC Voltage inputs to a DC Voltage, representative of the AC input and within the basic range of the instrument.

AC inputs are applied directly to the AC Converter which is comprised of an Operational Amplifier Rectifier, filter and gain determining network.

Dual FET Q1 is used to isolate the AC Converter and applies the AC input to Operational Amplifier U2 which amplifies the signal which will be rectified by CR11 & CR12. The resultant DC voltage is then filtered by C14 & C20 and applied to the Input Divider through resistor R9 and switches S4C & S5C. This DC voltage will then be attenuated to within the basic ranges of the instrument and then applied to the A-to-D Converter. The Amplifier Rectifier circuit has an adjustable gain determining network which is adjusted by means of range selection. RC networks are added in parallel by relays K6, K7 and K8 which are controlled by the Bipolar ROM. Transistors Q8 & Q9 act as overvoltage protection circuit.

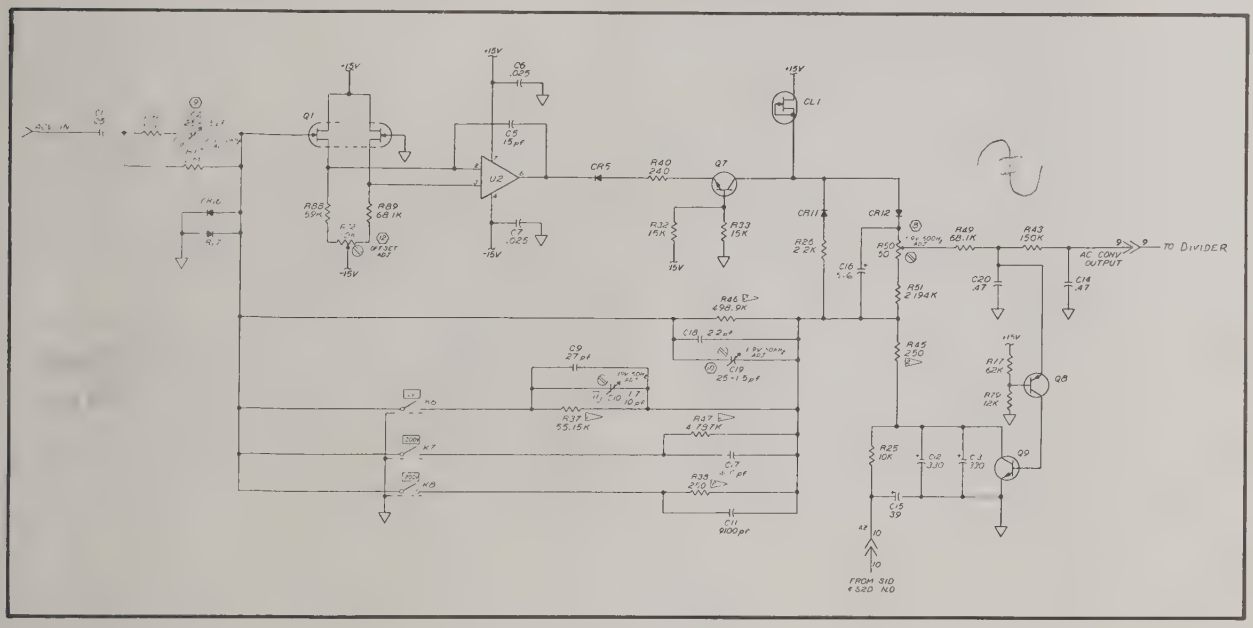


Figure 17.

CURRENT SHUNTS (Figure 18)

AC or DC current, from 0 to 2000mA is applied through fuse F1 and across protection diodes CR1, 2, 6 and CR8 and to the current shunt network comprised of resistors R2, R13 through R16. R2 is a four terminal shunt. Selection of the proper shunt is accomplished by switching of S6A, S7B, 8B, 9B and S10A. The voltage output of the current shunts is applied to one of two locations, AC converter for AC current input or directly into the A-to-D Converter in the case of VDC current input.

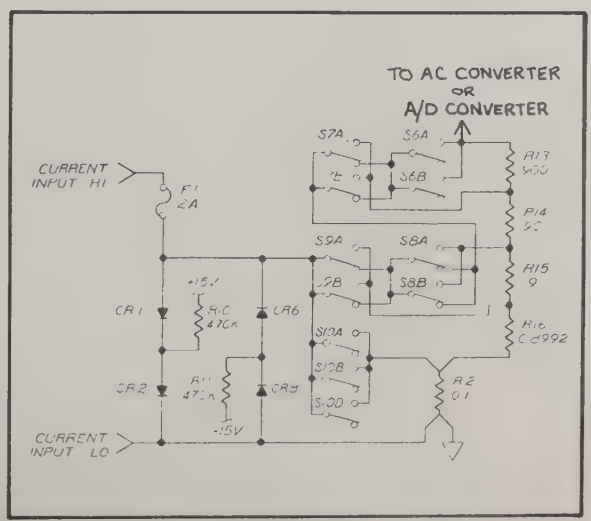


Figure 18.

OHMS CONVERTER (Figures 19 & 20, Table 2)

The purpose of the Ohms Converter is to supply a known current through the unknown resistance. This will result in a dc voltage drop across that resistor which is then measured by the A/D Converter.

Figure 19 is a simplified block diagram of the Ohms Converter, Input Divider, and A-D Converter, while Figure 20 is the Ohms Converter Schematic and Table 2 shows the Ohms Converter current output in the different ranges.

When the 2000KΩ range is selected all the range relays in the Input Divider K2-K4 and K5 in the Ohms Converter are open. This places all the Input Divider resistors (9990 KΩ) in series with the Ohms Converter 10K ohm output resistor (R27 and R28). The current ($I_X = 1\mu A$) from the Ohms Converter will develop two volts across an unknown resistance of 2000K ohms (an unknown resistance less than 2000K ohms will develop a voltage proportionately less than two volts). The voltage applied to the A-D Converter is also applied back to the ohms converter on the positive input of U1. The output and negative input of U1 will increase to match the voltage applied to the positive input. This action will maintain a constant current through the Input Divider resistance plus the 10K resistor network of the ohms converter to insure that the voltage drop across the unknown resistor (R_X) is directly proportional to the resistance.

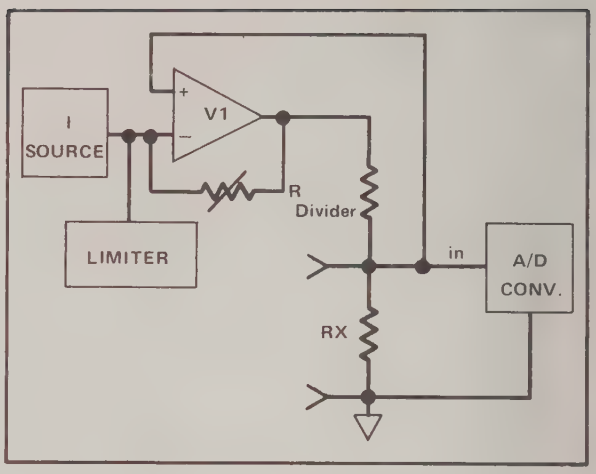


Figure 19.

8600 RANGE	OHMS CONVERTER OUTPUT CURRENT
20MΩ	0.1μa
2000KΩ	1μa
200KΩ	10μa
20KΩ	100μa
2KΩ	1ma
200Ω	1ma

Table 2.

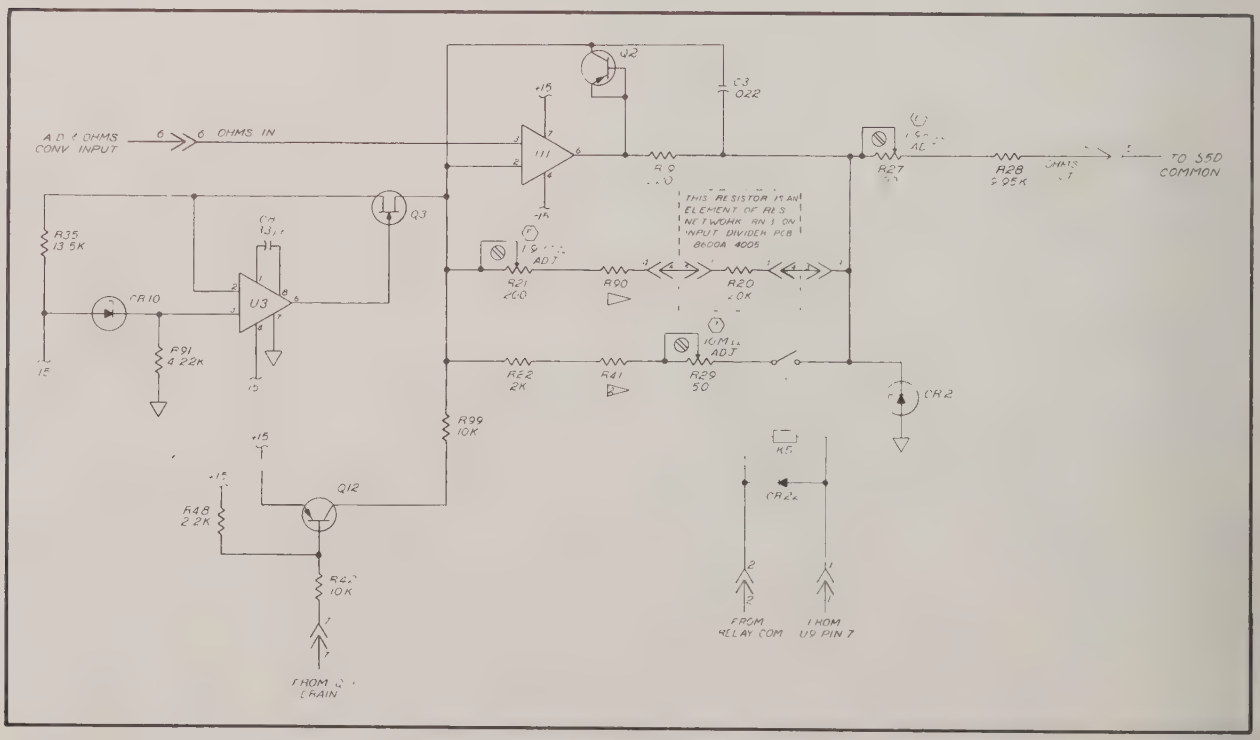


Figure 20.

NOTES

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